**April 16, 1963** N. H. LEHRER **3,086,139**

CATHODE RAY STORAGE TUBE

Filed Sept. 30, 1960 2 Sheets-Sheet 1

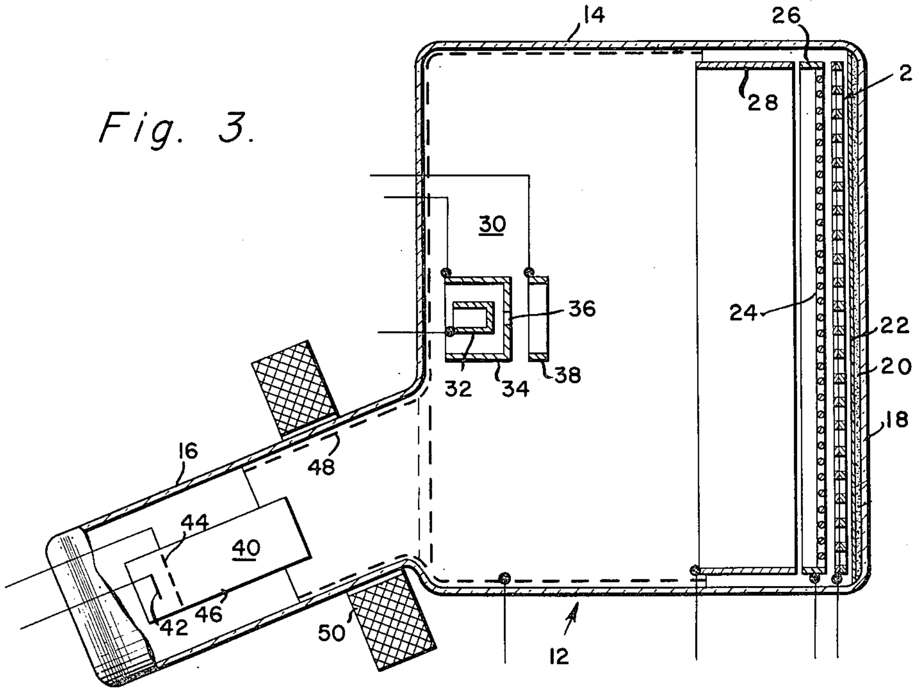

Fig. 3.

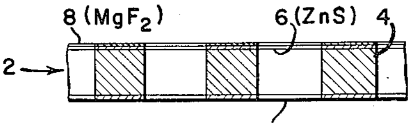

Fig. 2.

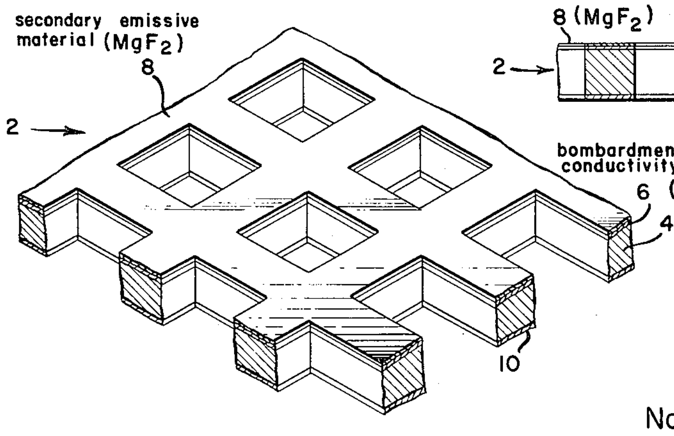

Fig. 1.

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Fig. 7.

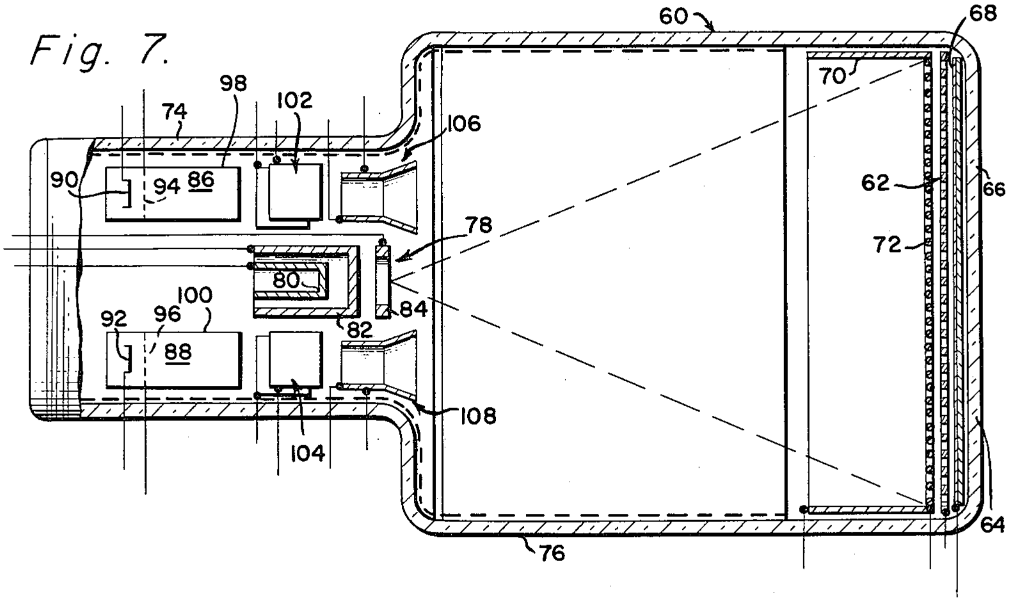


Fig. 6.

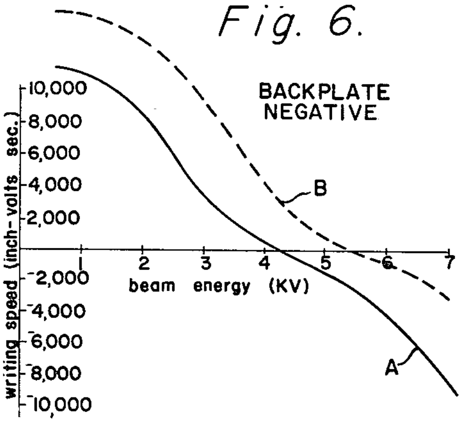


Fig. 4.

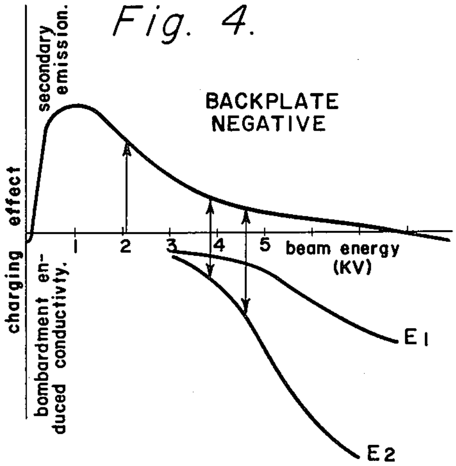
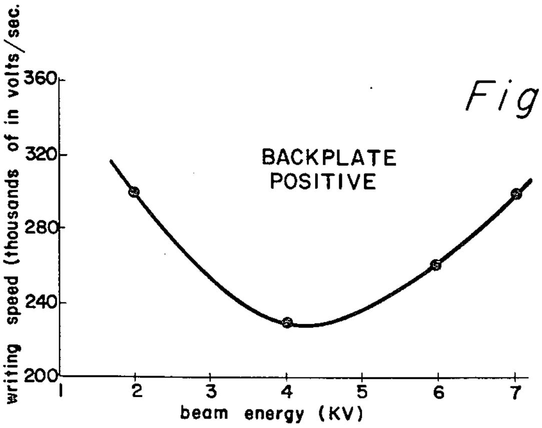


Fig. 5.



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# CATHODE RAY STORAGE TUBE

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17 Claims. (Cl. 315—12)

This invention relates to visual display storage tubes. More particularly, the invention relates to visual display storage tubes having a storage target employing both secondary electron emission and electron bombardment induced conductivity phenomena to achieve the selective erasure of stored displays or any portion thereof as well as the simultaneous presentation of both stored and non-stored displays.

The instant application is a continuation-in-part of an application for Letters Patent entitled "Cathode Ray Tube," Serial No. 7,163, filed February 8, 1960, which is a continuation-in-part of an application of the same title, Serial No. 795,727, filed February 26, 1959, now abandoned, both assigned to the same assignee of the present application.

Heretofore, the most practical and useful visual display storage tubes have utilized storage targets which have operated primarily, if not entirely, on the phenomenon of secondary electron emission from the storage surface. In these tubes the storage surface is normally or initially maintained negatively charged with respect to a source of flood or viewing electrons so as to prevent these electrons from passing through the storage target and illuminating the viewing screen. Upon scanning the secondary electron emissive surface with an electron beam of elemental cross-sectional area, modulated in accordance with signals representing the intelligence to be displayed, a pattern of positively charged areas is formed on the storage surface which areas permit the passage of flood electrons therethrough to illuminate the viewing screen in accordance with the pattern of positively charged storage areas on the storage target. A more detailed description of the structure and operation of such secondary emissive type storage tubes is found in U.S. Patent No. 2,790,929 to E. E. Herman and G. F. Smith.

Two methods have been suggested for achieving selective or spot erasure in such half-tone visual display storage tubes. An explanation of the relationship between the secondary electron emission ratio and electron energy level of the bombarding electron beam will be helpful in understanding these methods. As shown in the above-identified patent to Herman and Smith and in U.S. Patent No. 2,761,089 to A. V. Haeff, when an electron beam of less than about 40 volts of energy impinges on a secondary electron emissive surface, that surface becomes negatively charged because more electrons land thereon than leave it by secondary emission. In other words the secondary electron emission ratio is less than unity. Impingement of an electron beam having more than 40 volts of energy results in the surface becoming positively charged because more electrons leave this surface by secondary emission than land on it; thus the secondary electron emission ratio is greater than unity. This point at which the secondary electron emission ratio changes from less to greater than unity is called the "first crossover." If the energy level of the electron is increased, a second point is encountered at which the secondary electron emission ratio again becomes less than unity which point is termed the "second crossover." The energy level of the electron beam at the second crossover varies widely depending upon, among other things, the particular secondary electron emissive materials employed.

It will thus be appreciated that storage by means of secondary electron emission to produce positively charged areas on the storage surface is accomplished by the employment of an electron beam having an energy level intermediate the first and second crossovers above-referred-to. A typical electron beam energy level is about 2.5 kv. One method for achieving spot erasure is to employ an electron gun whose beam energy level is greater than that corresponding to the second crossover energy level. By this method any area of the target which is relatively more positive than the second crossover with respect to the cathode of this high energy gun will be driven negatively to cut off the flood electrons. One disadvantage of this method of spot erasure lies in the fact that variations in the second crossover for a given storage target can be as much as several hundred volts, resulting in non-uniform erasure which in turn produces variations in writing speed and brightness. Another disadvantage lies in the variation of the second crossover potentials of different materials which can be from 10 to 25 kv. resulting in problems of insulation and deflection.

A second method of achieving spot erasure in the above-described storage tubes is by employing an electron beam of an energy level lower than that corresponding to the first crossover energy level. Since the secondary electron emission ratio at this energy level is less than unity, any area of the target which is positive with respect to the flood gun cathode will be driven negatively to cut off the flood electrons. A disadvantage with this method is that focusing a beam of such relatively low energy level is extremely difficult thereby causing a loss in resolution. Also space charge limitations encountered in low energy beams does not permit appreciable current densities so that extremely slow erasure results.

Achieving the simultaneous display of stored and non-stored information in secondary emissive type storage tubes is also highly impractical. To provide such a display it is essential that the non-storage electron beam have no significant charging effect on the storage target. The most feasible approach is to employ an electron beam having an energy level corresponding to the potential of the second crossover. This procedure, however, is subject to the aforementioned disadvantages of deflection and insulation problems and non-uniformity and instability in the value of the second crossover across the storage surface. Such non-uniformity and instability may cause the beam to function properly in some areas, store in others, erase in still others, and perhaps even cause the charging effect to change under bombardment.

In view of the foregoing difficulties the art has understandably been searching for storage techniques based on a phenomenon other than just secondary electron emission. One such phenomenon is that of bombardment induced conductivity suggested by L. Pensak in "Physical Review," vol. 79, at page 171 (1950). Bombardment induced conductivity may be defined as the ability of an insulating film to conduct current when subjected to bombardment by relatively high-energy beams of ionizing particles such as electrons, neutrons, alpha particles and the like. However, the phenomenon of bombardment induced conductivity has not heretofore been successfully employed in visual display storage tubes because of the excessively high fields required across the storage dielectrics normally used. These fields must be of the order of $10^6$ v./cm. This may be more readily understood by consideration of the following characteristics of the bombardment induced conductivity materials of the prior art (i.e., silicon monoxide). The ratio of the current through the dielectric to the incident beam current (hereinafter referred to as the conduction ratio) must be high enough to permit operation with a potential drop across the dielectric not in excess of 30–40 volts. If the required potential drop for significant values of the conduction ratio results in a backplate potential greater than 30–40 volts positive, the flood electrons may strike the storage surface with sufficient energy to drive this surface to the collector potential resulting in erratic half-tone storage operation. On the other hand if the potential on the backplate exceeds about 20 volts negative, then the flood electrons may be unable to penerate the storage mesh (unless the mesh is made so coarse as to result in a considerable sacrifice in resolution). Thus, for example, a 60% transmission storage mesh having a pitch of 250 cannot be operated at D.C. potentials with negative voltages in excess of 20 volts except at very low brightness levels.

These factors thus mean that the backplate potential must be limited to about 30–40 volts positive in order to charge the surface positively. With these backplate voltages, in order to achieve the fields of $10^6$ v./cm. needed with known bombardment-induced conductivity material, such as silicon monoxide, thinner (i.e., 1000 to 2000 Angstroms) films are required. However, with such thin films of known bombardment induced conductivity materials several objections may be immediately raised which demonstrate why the principle of bombardment induced conductivity has not proven satisfactory heretofore for visual storage tube applications. In the first place it is extremely difficult to produce sufficiently insulating continuous thin films. In addition, one immediate consequence with a film of silicon monoxide 1000 to 2000 Angstroms thick is a five to tenfold increase in the capacity of the film which results in a significant decrease in writing and erase speeds. Also the maximum values of conduction available in such thin films are extremely small. These objections appear to be characteristic of the high resistivity bombardment induced conductivity materials known heretofore such as silicon monoxide and magnesium fluoride.

It is therefore an object of the present invention to provide an improved cathode ray tube storage target.

Another object of the invention is to provide an improved cathode ray tube storage target utilizing the phenomenon of bombardment induced conductivity.

Still another object of the invention is to provide an improved cathode ray tube storage target utilizing both the phenomenon of bombardment induced conductivity and the phenomenon of secondary electron emission.

Another object of the invention is to provide an improved cathode ray storage tube having a storage element utilizing the phenomenon of bombardment induced conductivity.

Yet another object of the invention is to provide an improved cathode ray storage tube having a storage element utilizing the phenomenon of bombardment induced conductivity without loss of writing speed or degradation of display resolution.

Another object of the invention is to provide an improved selective erasure cathode ray storage tube.

Still another object of the invention is to provide an improved cathode ray storage tube utilizing the phenomena of bombardment induced conductivity and secondary electron emission to accomplish the functions of storage and erasure.

These and other objects and advantages of the invention are achieved by providing a storage target in a cathode ray tube which target comprises a conductive support member having a thin film thereon of cubic zinc sulfide. It has been found that a cubic zinc sulfide storage surface is responsive to the energy level of an electron beam impinging thereon whereby at one beam energy level the principal effect is secondary electron emission greater than unity while at a different beam energy level the principal effect is bombardment induced conductivity. Thus while at the first beam energy level bombardment induced conductivity may occur, it is completely dominated or overridden by the secondary electron emission phenomenon. Such a storage target is capable of being charged in opposite electrical senses by selectively utilizing these two phenomena. It is thus now possible, by switching the electron beam energy level, to write or store information on the storage surface by one phenomenon and to erase by selective scanning any portion of the stored information by the second phenomenon. Thus, for example, a normally negatively charged storage target may be driven selectively positive by secondary electron emission in accordance with information to be stored by scanning the target with an electron beam of 2.5 kv. Bombardment of these positively charged portions with an electron beam of 7.0 kv., for example, induces those portions to become conductive so that they return to or assume the normally negative potential of the storage target. It is also possible by utilizing an electron beam having an intermediate energy level (i.e., 4.5 kv.) to cause the beam to pass through the storage target without altering the stored pattern or other potential conditions of the target. Thus stored information may be displayed simultaneously with non-stored or "live" information.

The practicability and usefulness of the storage target of the present invention results from the fact that films of cubic zinc sulfide exhibit significant bombardment induced conductivity at fields in the order of $10^5$ v./cm., which is a factor of 10 less than that required with known high resistivity dielectric material such as silicon monoxide and magnesium fluoride. Thus films of cubic zinc sulfide may be formed thin enough (i.e., less than 2 microns) on a support mesh as to permit operation with backplate potentials not exceeding 30–40 volts positive or 20 volts negative while utilizing electron beam energies of a reasonably practical maximum level (i.e., 7.0 kv.) in order to obtain bombardment induced conductivity. In addition, it has been found that such thin films of cubic zinc sulfide are not troubled by capacity effects which affect the writing and erase speeds because they do not have to be made as thin as the prior art materials. Furthermore, the resistivity available in thin films of cubic zinc sulfide are great enough to permit the storage of potentials without leakage or breakdown over long periods of time and usage.

The invention will be described in greater detail by reference to the following drawings in which:

FIGURE 1 is a cut-away perspective view of the storage target of the present invention;

FIGURE 2 is a cross-sectional elevational view of the storage target shown in FIGURE 1;

FIGURE 3 is a partially cross-sectional and partially schematic view of a cathode ray storage tube employing the storage target of the present invention;

FIGURE 4 is a plot showing the charging characteristics of the storage target of the present invention for different electron beam energy levels when the storage target backplate potential is negative;

FIGURE 5 is a plot showing the writing speed characteristics of the storage target of the present invention for different electron beam energy levels when the storage target backplate potential is positive;

FIGURE 6 is a plot showing the writing speed characteristics of the storage target of the present invention for different electron beam energy levels when the storage target backplate potential is negative; and

FIGURE 7 is a partially cross-sectional and partially schematic view of another cathode ray storage tube employing the storage target of the present invention.

Referring now to FIGS. 1 and 2 a storage target 2 according to the invention is shown comprising a nickel mesh 4, which may be electroformed, having disposed on one side thereof a thin layer or film 6 of cubic zinc sulfide which has both secondary electron emission and bombardment induced conductivity properties. The nickel mesh 4 may have from 100 to 400 meshes per inch, preferably 250 meshes per inch, and a thickness of about 1 to 2 mils. Such a mesh with a pitch of 250 meshes per inch will have an over-all transparency of about 60%.

The cubic zinc sulfide layer 6 is disposed coextensive with the meshes of the screen 4 and may be about one to two microns thick, for example. Thicker films are unsatisfactory for the purposes of the present invention because of the excessively high backplate potentials required. The cubic zinc sulfide film 6 may be formed on the mesh 4 by an evaporation process performed in a conventional manner except that the mesh 4 is maintained at a temperature of about 200° C. during evaporation. Alternatively, the zinc sulfide may be deposited on the nickel mesh 4 by a conventional evaporation process not involving the heating of the mesh during evaporation. However, in this alternate method the nickel mesh is first etched in an acid bath to expose its lattice structure; thereafter the zinc sulfide is evaporated and deposited onto the etched mesh. The coated mesh is then aged at a temperature of about 80° to 100° F. for a few days in order to achieve conversion of the zinc sulfide to the cubic lattice form. After this aging process the material while cubic, is unstable and may return to the hexagonal form if heated or exposed to light in vacuum. By heating the coated mesh in air at about 300° C. for about 15 minutes the material will become stabilized to withstand light and heat in vacuum.

It is also desirable and preferred to provide a supplementary layer 8 of secondary electron emissive material over the cubic zinc sulfide film 6 in order to enhance the secondary electron emission characteristics of the storage target. Thus, for example, a thin film 8 of magnesium fluoride may be evaporated onto and over the layer 6 of cubic zinc sulfide. The film 8 of magnesium fluoride may be about 500 Angstroms thick, for example. This supplemental secondary electron emissive layer should be thin enough to allow a high energy level (i.e., 7 kv.) electron beam to penetrate therethrough to the cubic zinc sulfide layer 6 so as to raise electrons therein to the conductive energy level and thick enough to provide high secondary electron emission when bombarded by a relatively low energy level (i.e., 2.5 kv.) electron beam.

It may also be advisable to evaporate a thin film 10 of gold onto and over the side of the mesh 4 opposite the side on which the layer 6 of cubic zinc sulfide is deposited in order to cover any dielectric particles which may have inadvertently been deposited on this side. Such particles tend to charge in an irregular pattern making the display non-uniform.

Referring now to FIGURE 3 a half-tone visual display cathode ray tube 12 is shown incorporating the storage target 2 of the present invention. The tube 12 comprises an evacuated envelope formed by a comparatively large cylindrical section 14 and a narrower neck portion 16 communicating therewith at one side thereof (hereinafter referred to as the neck or gun side). The neck section 16 may be disposed, as shown, at an angle with respect to the main longitudinal axis of the larger cylindrical section 14. The side of the large cylindrical section 14 opposite the neck side comprises a face-plate 18 over the inner surface of which is a layer 20 of phosphor material covered with a thin film of aluminum 22. Adjacent and coextensive with the face-plate or viewing screen 18 is the storage target 2 as described previously and shown in FIGURES 1 and 2. Continuing to proceed from the viewing screen end of the tube toward the gun section, a collector grid 24 is disposed adjacent and coextensive with the storage target 2. The collector grid 24 comprises a conductive screen supported about its periphery by an annular ring 26. The transparency of this screen is preferably of the order of 80%; the function of the grid 24 is to collect secondary electrons emitted from the storage target 2. Adjacent the collector grid 24 is a collimating electrode 28 in the form of a cylindrical can the purpose of which is to collimate flood or viewing electrons from the flood gun 30 which is disposed at the gun side of the tube section 14. The flood gun 30, which may be of the longitudinal axis of the larger cylindrical portion 14 of the tube 12, comprises a cathode 32 and an intensity electrode 34 which encloses the cathode 32 except for a small aperture 36 disposed over the central portion of the cathode 32. An annular electrode 38 is disposed adjacent the intensity electrode 34 and coaxially with respect to the longitudinal axis of the tube 12 which also passes through the center of the aperture 36 in the intensity electrode 38.

The neck portion 16 of the tube 12 houses an electron gun 40 which may be of conventional construction. The gun 40 comprises a cathode 42, an intensity electrode grid 44, and a cylindrical beam-forming section 46.

An equipotential region is maintained throughout the neck portion 16 of the larger cylindrical section 14 of the tube 12 by means of a conductive layer 48 which may be coated over the interior surfaces of the tube as shown. During operation, a potential of about 5 volts positive may be maintained on this conductive layer.

Before proceeding with an explanation of the several modes of operating the storage tube of the present invention, it will be helpful to compare some of the properties of the present bombardment induced conductivity storage target with those of the prior art and to consider the charging characteristics of the storage target of the present invention.

Heretofore, fields of the order of $10^6$ volts per centimeter were required in order to produce significant bombardment induced conductivity effects in materials of sufficiently high resistivity for use in direct-view half-tone storage tubes. Hence these prior art films would not break down (i.e., become conducting) until fields of about 2 to $3 \times 10^6$ volts per centimeter were applied across the dielectric. Thus the storage surface of a film of such a material one micron thick would, under continual bombardment by electrons whose velocity is such as to land with a secondary emission ratio greater than 1, become charged to the collector potential. Such charging interferes with the operation of the half-tone storage tube as well as making possible permanent damage to the viewing screen and storing surface. With a storage surface according to the present invention, substantial bombardment induced conductivity effects can be obtained with fields in the order of $10^5$ volts per centimeter. Breakdown in these films occurs at about 3 to 5 times $10^5$ volts per centimeter and therefore a 1 micron film cannot support more than 30 volts across it before breakdown. This prevents the storage surface from being driven to the collector potential by the bombarding action of electrons which land with an energy such that their secondary emission is greater than 1. In addition it is possible for the flood beam to restore the potential of the surface to flood cathode potential. One of the significant consequences of this property of the dielectric of the present invention is that it is possible to employ equilibrium secondary emission charging to flood gun cathode potential. This means that the storage surface can be selectively charged positively to an equilibrium potential by secondary emission, which is not the collector potential, and which corresponds to the full brightness condition of the storage surface. Thus it is possible for the first time to operate a half-tone storage tube between two equilibrium potentials one of which is the flood gun cathode potential and the other of which is substantially the backplate potential. The equilibrium potential to which the tube may be charged is determined by the beam energy. This permits presenting displays of uniform brightness.

FIGURE 4 is a plot of the secondary emission and bombardment induced conductivity charging effects vs. primary beam energy when the storage target backplate potential is negative and a target comprising a layer of cubic zinc sulfide coated with a thin film of magnesium fluoride is employed. It will be noted that with a beam energy of about 1 kv., charging (which means charging the potential of the storage surface) is at a maximum and is almost entirely due to the secondary electron emission phenomenon, any charging due to bombardment induced conductivity being negligible and rather completely overridden by the secondary emission effect. Thus with a primary beam energy of from 1 to 4.5 kv. the storage target is charged positively by the secondary emission phenomenon.

At about 4.5 kv. secondary emission still occurs but bombardment induced conductivity effects have increased to the point where both phenomena charge the storage surface in equal but opposite electrical senses, hence the storage surface potential will be undisturbed when the storage target is bombarded by a beam of about 4.5 kv. With beam energies greater than about 4.5 kv. the bombardment induced conductivity effect increases and rather completely over-rides the secondary emission effect which continues to diminish. The net charging effect on the storage surface hence is to drive it negatively to an equilibrium potential by the bombardment induced conductivity effect.

It will thus be appreciated from a study of the charging characteristics as shown in FIGURE 4 that the storage target of the present invention utilizes two phenomena to produce charging effects in opposite electrical senses which effects may be balanced so as result in no net charging effect in either electrical sense. This is possible because there is a continuous range of electron beam energy levels where both secondary electron emission and bombardment induced conductivity occur and because at different portions of this range either of these phenomena can be made dominant or the two phenomena can be balanced. The capability of balancing these two phenomena is of utmost significance where it is desired to provide a storage target which can be "written through" to present direct or "live" information without altering the potentials on the storage target. Thus if these two phenomena did not overlap over a continuous range of electron beam energy levels, one could still store by one phenomenon (i.e., secondary emission) and erase by the other (i.e., bombardment induced conductivity) simply by switching the beam energy levels but there would be no energy level where one could "write through" since charging the beam energy level only would result in establishing one of the two phenomena as the dominant one.

FIGURE 5 is a plot of the "writing" or charging speed in thousands of inch-volts per second vs. primary beam energy to produce a potential drop of about 7 volts across the storage surface when the storage target backplate potential is positive. Again, this plot is for a storage target comprising a layer of cubic zinc sulfide coated with a thin film of magnesium fluoride. It should be remembered that by charging or writing speed we are talking about the speed of charging the potential of the storage surface. Charging speed is shown to be at a maximum for beam energies of less than about 2 kv. and more than about 7 kv. It is at a minimum for a beam energy of about 4.5 kv. Because greater display resolution can be obtained with a primary beam energy of 2 to 3 kilovolts, charging by secondary emission is preferably accomplished by utilizing a beam of about 2.5 kv. rather than 1 kv. or less at a slight sacrifice in charging speed. Charging by bombardment induced conductivity is preferably accomplished by utilizing a beam of about 7 kv. in order to achieve a charging speed comparable to that of secondary emission charging which is about 300,000 inch-volts per second. Beam energies of greater than 7 kv. begin to introduce serious problems of electrical insulation.

In FIGURE 6 the plot shows the "writing" or charging speed in thousands of inch-volts per second vs. primary beam energy to produce a potential drop of about 7 volts across the storage surface where the storage target backplate potential is negative. It should be understood that the storage tube may be operated in either mode, that is, with the storage target backplate at either positive or negative potentials as will be more fully described hereinafter. Curve A is the plot for storage target comprising a layer of cubic zinc sulfide on a conductive substrate while Curve B is the plot for a target comprising a layer of cubic zinc sulfide with a thin film of magnesium fluoride thereover. It will be observed that the magnesium fluoride-cubic zinc sulfide target is characterized by a faster charging speed as shown by Curve B than the cubic zinc sulfide target (Curve A). This is due to the fact that secondary emission from the magnesium fluoride film enhances the charging effect of the impinging electron beam. In comparison with the plot of FIGURE 5, it will be noted that writing or charging speed is significantly lower when the storage target backplate potential is negative (as shown in the plot of FIGURE 6). This is because the charging is accomplished additively by both secondary emission and bombardment induced conductivity phenomena when the backplate potential is positive.

Referring again to the plot shown in FIGURE 6, it will be observed that maximum charging speed is obtained with beam energies of less than about 2 kv. and more than about 7 kv. and is minimal at about 4.4 and 5.5 kv. for the cubic zinc sulfide target and the cubic zinc sulfide-magnesium fluoride target, respectively. It should be remembered that the writing speeds shown in FIGURE 6 are for producing a potential drop of about 7 volts across the storage surface and these speeds will be greater for lower potential drops. When operating a storage tube according to the present invention with the storage target backplate potential negative, it is preferable to utilize beams having energy levels of about 2.5 kv. and 7 kv. in order to obtain greater display resolution even though there is some sacrifice in writing speed.

Operation of a selective erasure storage tube may be accomplished with the storage target backplate potential negative as follows. A potential of about 9 volts negative relative to ground is applied to the nickel mesh support 4 of the storage target. The flood or viewing gun cathode 32 may be maintained at ground potential while the intensity electrode 34 and the annular electrode 38 may be maintained, respectively, at potentials of about 20 volts negative and 100 volts positive with respect to ground. Under these circumstances flood electrons from the gun 30 will be prevented from penetrating the storage target 2 (because of the 9-volt negative potential thereon). Hence the flood or viewing electrons cannot reach the viewing screen and excite it into luminescence. This is the initial "dark" condition of the tube and in this mode of operation, information is displayed as "white on black."

To store and display information, the storage target 2 is scanned by an electron beam of elemental cross-sectional area having an energy level of about 2.5 kilovolts. This beam may be generated by means of the electron gun 40 in the neck portion 16 of the tube. The cathode 42 of this gun may be maintained at a potential of about 2000 volts negative with respect to ground while the intensity grid 44 may be at a potential of about 75 volts negative with respect to the potential of the cathode **42**. The electron beam produced by this gun is modulated and scanned in accordance with information-representative signals derived and applied by conventional techniques. The beam is deflected horizontally and vertically electromagnetically, as shown, by means of the deflection yoke **50** which is positioned around the neck **16** of the tube.

Areas of the storage target **2** impinged by the 2.5 kv. beam in accordance with the information to be displayed are charged positively due to the emission of electrons therefrom which are collected by the collector grid **24** which may be maintained at a potential of 120 volts positive with respect to ground in order to accomplish this function. Viewing or flood electrons from the flood gun **30** may then pass through the storage target **2** at these areas of positive potential and are then accelerated to the viewing screen by means of a potential of about 6,000 volts positive with respect to ground which may be maintained on the aluminum film **22** of the viewing screen. In this manner the information is displayed as "white on black" and the display may be maintained and viewed as long as desired.

Non-stored or "live" information may also be simultaneously displayed by switching the potential of the cathode **42** of the charging gun **40** to about 4.5 kilovolts. As explained previously a beam of this energy level does not produce any change in the potential of the storage surface. Hence, the beam passes through the storage target **2** without altering the potential of either positively or negatively charged portions. In this respect the storage tube of the present invention is a marked improvement over storage tubes of the past wherein storage was achieved solely by the phenomenon of secondary emission.

Stored potentials on the storage target **2** may be selectively erased by switching the potential of the cathode **42** of the charging gun **40** to about 7.0 kilovolts and scanning the storage target with the beam of this energy level in accordance with signals representing the information to be erased. The impingement of a beam of 7.0 kv. on portions of the storage target results in these portions being charged negatively to about the potential of the nickel support mesh 4 (−9 volts) by means of the phenomenon of bombardment induced conductivity, as explained previously.

It will be noted that the storage tube shown in FIGURE 3 and described so far herein has but one charging electron gun whose cathode potential is switched to provide beams of different energy levels (2.5 kv., 4.5 kv., and 7.0 kv.) so as to permit storing, "writing-through," and erasing selectively. When only a single charging gun is provided the operations of storing, "writing-through," and erasure cannot be accomplished simultaneously.

Referring now to FIGURE 6, a multiple gun cathode ray storage tube **60** is shown which incorporates a storage target **62** according to the present invention. By incorporating more than one electron gun (other than the flood gun) in the tube, any two of the three operations (i.e., storing, erasing and write through) may be accomplished simultaneously. As used herein when reference is made to the number of electron guns, the flood gun is not intended to be included therein. It is also possible to include three electron guns whereby all three operations may be achieved simultaneously. However, the tube **60** shown in FIGURE 6 is provided with only two electron guns which permits selective storage and selective spot erasure simultaneously, although either of the two guns may be switched to an appropriate electron beam energy level for the purpose of "writing through" the storage target **62**.

The "front" end of the multiple gun storage tube **60** may be substantially identical to the front end of the storage tube shown in FIGURE 3 and described previously herein. A phosphor layer **66** is disposed on the faceplate **64**. An electron transparent aluminum conducting film **68** is disposed over the phosphor layer **66**. Next the storage target **62**, identical to the storage target shown in FIGURES 1 and 2, is provided. A collector electrode **70** which may be in the form of a cylindrical can having a screen **72** disposed across an end thereof is provided adjacent the storage target **62**. The tube neck **74**, which may be coaxial with the bulb portion **76** of the tube **60**, has a relatively large diameter in order to house the electron guns required in this embodiment. Coaxially disposed within the neck **74** and adjacent the point whereat the neck **74** opens into the bulb portion **76**, a flood or viewing gun **78** is disposed. This flood gun **78** includes a cathode **80**, an intensity electrode **82**, and an annular electrode **84**. This flood gun may be substantially identical to the flood gun **30** shown in FIGURE 3 and described heretofore in connection therewith.

Likewise disposed within the neck portion **74** of the storage tube **60** are two electron guns **86** and **88** which may be substantially identical to each other and likewise identical with the electron gun **40** shown in FIGURE 3. These electron guns **86** and **88** include, respectively, cathodes **90** and **92**, intensity grids **94** and **96**, and gun forming sections **98** and **100**. As shown these beams are disposed off the major axis of the tube **60**. The electron beams produced by the two electron guns **86** and **88** may be deflected either electromagnetically or electrostatically. In the embodiment of FIGURE 6 electrostatic deflection of these electron beams is achieved by means of the horizontal deflecting plates **102** and **104** and the vertical deflection plates **106** and **108** which plates are disposed coaxially with respect to the axis of the electron guns **86** and **88**, respectively.

Operation of this tube may be substantially the same as operation of the tube shown in FIGURE 3 except that any two functions such as storing and erasing or displaying stored and live information may be achieved without the necessity of switching the energy beam levels of either of the electron guns **86** or **88**. In this arrangement it may be desirable to operate one gun permanently as a storing or writing gun while the other gun may be adapted to have its beam energy switched between the levels needed for selective erasure or write-through.

As will be apparent from the foregoing, the stored information as written on the storage surface is displayed as "white on black." That is, the tube is operated so that the storage surface, prior to being scanned by the write beam is initially at a negative potential so that flood or viewing electrons cannot penetrate the storage target and excite the viewing screen into luminescence. The storage target is "opened" up by modulating the write beam in accordance with stored intelligence which will be displayed as "white on black" information. Likewise, scanning with an electron erase beam of the order of 4.4 kilovolts, which will write through the storage target without changing its potential, also will produce a "white or black" display.

The tube of the present invention may be operated in another manner so as to provide displays of high resolution without loss of writing speed. When "writing" is accomplished by secondary emission, maximum resolution is not usually realized because low beam energies are required to obtain high secondary emission ratios while maximum resolution is obtained by employing higher beam energies. As shown by the curve in FIGURE 5 the writing speed is maximum with a beam energy of less than about 1000 volts. However, as has been explained previously, in order to obtain greater resolution a compromise is made and the charging beam is maintained at 2 to 3 kilovolts which results in 50 to 70 resolvable lines per inch at nominal values of the beam current (i.e., 25 to 50 microamperes). As noted previously when the beam energy is about 4.4 kilovolts it will write through the storage target and produce an instantaneous display on the viewing screen and when a beam energy of greater than 4.4 kilovolts is used, for example, 7 kilovolts, the storage surface is driven negative by the bombardment induced conductivity phenomenon and any positively charged storage patterns thereon are erased.

It is possible to operate the tube of the invention by first scanning the storage surface with the low energy beam thereby driving the storage surface positive by secondary emission. This will permit flood electrons to pass through the entire storage target and illuminate the entire area of the viewing screen. Thus the initial condition of the storage surface in this manner of operation is a full brilliance condition. The high energy gun, suitably modulated in intensity in accordance with the intelligence to be stored and displayed, is then scanned across the storage surface driving portions thereof negative by bombardment induced conductivity in accordance with the intelligence to be stored and displayed. Since the flood electrons cannot now penetrate the storage surface at these negatively charged portions, a dark image or black on white display of the intelligence is formed. Erasure of this image or any portion thereof is accomplished by scanning the storage surface with the low energy beam which will drive the negatively charged portions positive. In this manner, writing at a faster writing speed is accomplished by a high energy beam resulting in much greater resolution. For example, 100 to 120 resolvable lines per inch are obtained at beam current values of 25 to 50 microamperes. If a display of information as black on white is not desired, the intelligence or video information on the grid of the high energy gun may be inverted so as to obtain a white on black display; in other words, the high energy beam will drive portions of the storage surface corresponding to the background negative.

There thus has been described a new and improved cathode ray storage tube utilizing the phenomenon of bombardment induced conductivity effectively and in a practical manner for the first time. In addition, a storage tube has been described which permits selective erasure of stored information and the presentation of "live" information simultaneously with the display of stored information. Furthermore, several embodiments of the invention have been suggested and described to demonstrate the versatility of the invention in different storage tube arrangements and modes of operation.

What is claimed is:

1. A storage target for a storage tube comprising a conductive support member having a layer of cubic zinc sulfide disposed over at least a portion thereof, and a layer of secondary emissive material disposed over said layer of cubic zinc sulfide.

2. The storage target according to claim 1 wherein said secondary emissive material is magnesium fluoride.

3. In a direct-view storage tube wherein an electric potential charge pattern on a storage target is controlled by a scanning electron beam to control the flow of flood electrons to a viewing screen, the improvement comprising said storage target comprising a metallic support member with a layer of cubic zinc sulfide disposed over at least a portion thereof.

4. A storage target for a storage tube comprising a conductive support member, a layer of cubic zinc sulfide disposed over at least a portion of said conductive support member, said layer exhibiting substantial bombardment induced conductivity with a field of $10^5$ volts centimeter and breakdown at fields $3\text{–}5 \times 10^5$ volts per centimeter, said layer further exhibiting secondary electron emission at a ratio greater than unity.

5. The storage target according to claim 4 wherein a layer of secondary emissive material is disposed over said layer of cubic zinc sulfide.

6. The storage target according to claim 4 wherein a layer of magnesium fluoride is disposed over said layer of cubic zinc sulfide.

7. A storage target for a storage tube comprising a conductive support member, a layer of cubic zinc sulfide disposed over at least a portion of said conductive support member, said cubic zinc sulfide exhibiting substantial bombardment induced conductivity with a field of $10^5$ volts per centimeter and breakdown at fields of $3\text{–}5 \times 10^5$ volts per centimeter, and a layer of secondary emissive material disposed over said layer of cubic zinc sulfide.

8. A storage target for a storage tube comprising a conductive support member, a layer of cubic zinc sulfide disposed over at least a portion of said conductive support member, a layer of secondary emissive material having a secondary electron emission ratio greater than unity disposed over said layer of cubic zinc sulfide, said cubic zinc sulfide layer exhibiting substantial bombardment induced conductivity with a field of $10^5$ volts per centimeter and breakdown at fields of $3\text{–}5 \times 10^5$ volts per centimeter and being thin enough to prevent breakdown with fields whose potentials are beyond the first cross-over point at which secondary electron emission is greater than unity.

9. In a cathode ray storage tube having means for forming electron beams of different energy levels and a storage target adapted to be scanned by said beams for controlling the flow of flood electrons to a viewing screen, the improvement comprising; said storage target comprising a metallic support member having a layer of cubic zinc sulfide disposed over at least a portion thereof facing said means for forming said electron beams.

10. A cathode ray storage tube comprising means for forming electron beams of different energy levels, and a storage target comprising a conductive support member having a layer of cubic zinc sulfide disposed over at least a portion thereof facing said means for forming said electron beams, and a layer of secondary emissive material disposed over said layer of cubic zinc sulfide.

11. A cathode ray storage tube comprising means for forming an electron beam of a first energy level, means for forming an electron beam of an energy level different from said first energy level, and a storage target comprising a metallic support member having a layer of cubic zinc sulfide disposed over at least a portion thereof facing said beam forming means.

12. The cathode ray storage tube according to claim 11 wherein a layer of magnesium fluoride is disposed over said layer of cubic zinc sulfide.

13. A cathode ray storage tube comprising means for forming electron beams of different energy levels, and a storage target comprising a metallic support member having a layer of cubic zinc sulfide disposed over at least a portion thereof facing said beam forming means, said layer exhibiting substantial bombardment induced conductivity with a field of $10^5$ volts per centimeter and breakdown at fields of $3\text{–}5 \times 10^5$ volts per centimeter, said layer further exhibiting secondary electron emission at a ratio greater than unity.

14. The cathode ray storage tube according to claim 13 wherein a layer of magnesium fluoride is disposed over said layer of cubic zinc sulfide.

15. A cathode ray storage tube comprising means for forming electron beams of different energy levels, and a storage target comprising a metallic support member having a layer of cubic zinc sulfide disposed over at least a portion thereof facing said beam forming means, said layer exhibiting substantial bombardment induced conductivity with a field of $10^5$ volts per centimeter and breakdown at fields of $3\text{–}5 \times 10^5$ volts per centimeter and exhibiting secondary electron emission at a ratio greater than unity and being thin enough to prevent breakdown with fields whose potentials are beyond the first cross-over point at which secondary electron emission is greater than unity.

16. A half-tone visual display storage tube comprising a storage target including a conductive support member having a layer of cubic zinc sulfide on at least a portion of one side thereof, a viewing target disposed adjacent to said storage target on the side thereof opposite to said one side, an electron source for directing flood electrons uniformly over said storage target, means for collecting secondary electron emitted from said storage

target, means for producing electron beams of different energy levels.

17. The half-tone visual display storage tube according to claim 13 wherein said means for producing said electron beams of different energy levels includes at least two electron guns.

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